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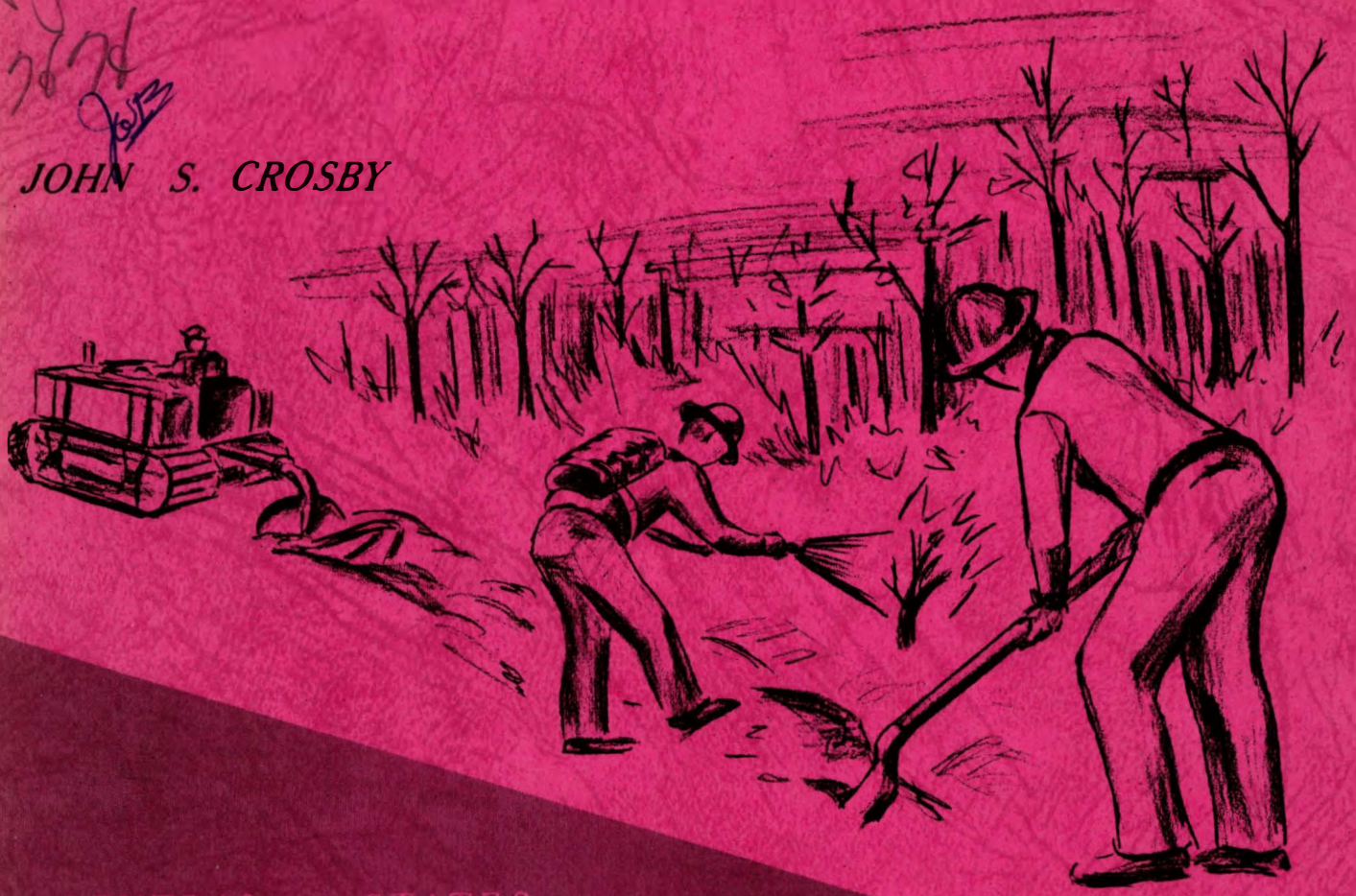

CENTRAL STATES
FOREST EXPERIMENT STATION

COLUMBUS, OHIO — W. G. McGINNIES, DIRECTOR

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Cover.--

This report is from the
Division of Forest Management
CENTRAL STATES FOREST EXPERIMENT STATION

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(Maintained in cooperation with the
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Agricultural Experiment Station
Columbia, Missouri)

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PROBABILITY OF

FIRE OCCURRENCE

CAN BE PREDICTED

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Northern Ozark Forest Research Center

The success of forest-fire suppression depends a great deal upon the speed and strength of attack. Maximum speed is always an objective. In contrast, however, the strength and distribution of the fire-control organization must be adjusted to the daily changes in fire danger in order to attain the fire-control objectives within reasonable limits of cost. Too much strength is costly--too little is dangerous.

As a guide in fixing the strength of the fire-control organization, several meters have been developed to help predict the occurrence and behavior of fires. In Missouri, Illinois, Indiana, and Ohio, the Central States Danger Meter is used.

Fire and weather records for the past 7 years for the Clark National Forest (now divided between the Missouri and the Shawnee) have been carefully examined to more specifically define the relationship that might exist between fire occurrence and the ratings of this meter. The results, reported here, show that the meter can be used not only to measure the day-by-day burning index, but also to predict the probability of fires occurring.

THE METER AND ITS RELATION TO FIRE OCCURRENCE

The Central States Danger Meter is based upon wind velocity, relative humidity, condition of vegetation, amount of the last rain, and number of days since the last rain. Meter ratings on an arbitrary scale from 0 to 100 are obtained from various combinations of these values. A rating of 0 represents "safe" conditions; a rating of 100 represents the worst possible combination of conditions.

Three fire-danger meter readings are taken daily on each ranger district--at about 8 a.m., 12 noon, and 5 p.m. In this study the highest of the three ratings was called "the maximum daily rating." Summaries of (1) the total number of days in the study period, (2) the number of days on which "reportable"[1/] fires occurred (fire-days), (3) the number of reportable fires, and (4) the area burned were made by these "maximum daily ratings" for each district and month.

The average number of fires per day for days having a given meter rating is used as a measure of fire occurrence for that meter rating. Such averages were computed for individual meter ratings from 0 to 24 and for small groups of ratings greater than 24.

These averages also represent the probability of fire occurrence. For example, if there were 10 reportable fires in 100 days when the maximum daily rating was 4, the average number of fires is 0.1 per day or 1 fire per 10 days. The probability is therefore about 1 in 10, or 10 percent, that a fire will occur when the maximum daily rating is 4.

Seven-year records for the months of February, March, April, October, and November show that the average number of reportable fires per day on the Clark National Forest varies almost directly as the maximum daily meter rating. Regressions were computed from the combined district data for ratings from 0 to 50 for each month studied (fig. 1) and the correlations were found to be highly significant.[2/] So apparently the average probability of fire occurrence can be estimated from the various meter ratings with some confidence.

1/ Briefly, a reportable fire is one that occurs on, or threatens, the protected area and on which suppression action is taken by the Forest Service.

2/ Values for ratings of 50 to 100 were omitted from the computations since they are somewhat erratic and involved less than 1 percent of the days and less than 3 percent of the fires.

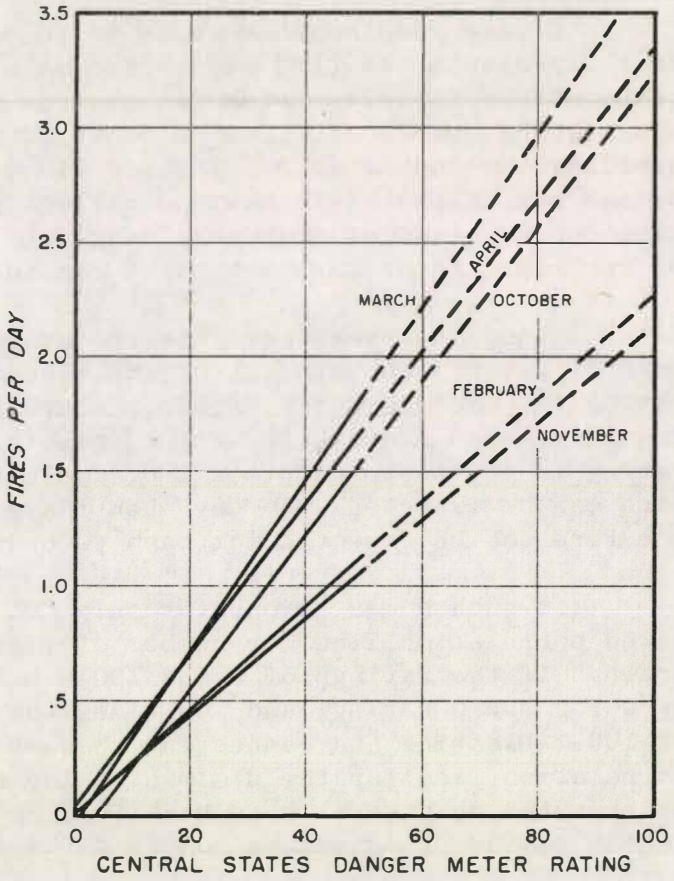


Figure 1.--Average number of fires per day by meter ratings and months.

INDIVIDUAL DISTRICT ESTIMATES ARE NEEDED

The straight lines in figure 1, based on the combined data for all the districts on the forest, represent good statistical correlations between number of fires per day and meter ratings. However, the sample of data for individual districts is small and the data are less apt to be so well correlated. Moreover, the procedure to obtain these lines by regression is tedious. Nevertheless, to be of greatest local value, the relationships for each district must be considered separately.

Since a good linear correlation was obtained from the combined district data, it is reasonable to assume that the data for each district are similarly correlated even though the correlation is not so clear-cut because of a smaller sample and local peculiarities of risk. So, if the most likely slope of the line for each district can be determined, the local probability of fire occurrence can be estimated from the line. This line may be equally useful in helping to determine how the actual occurrence of fires varies and what the pattern of these variations is.

A very good approximation of the straight-line correlation that represents the fire occurrence on a district can be obtained quite simply by using "risk factors."[3] The risk factor is actually the average number of fires per unit of rating. It is found by dividing the number of fires for a given period (usually a month) by the sum of the daily maximum ratings for the same period. If data for a period of 5 or more years are used, a good mean value of the risk factor for each month considered is obtained.

Since the risk factor is the average number of fires per unit of rating, the product of the risk factor and the maximum rating for a certain day is the number of fires to be expected for that day. For example, if the average risk factor is 0.025 and the rating is 40, the product is 1.0, indicating that an average of one fire can be expected on a day when the rating reaches 40, or that one fire can be expected for each 40 units of rating.

If such computations for only two ratings are made, an estimated correlation line for number of fires per day can easily be drawn. If the ratings of 0 and 100 are selected, the values will be 0 for the 0 rating, and 100 times the risk factor for the rating of 100. Plotting and connecting these points produces an estimated correlation line for the district. The number of fires that could be expected on days with each rating, as determined by the risk-factor method, is shown by months for a typical district in figure 2.

The combined district data for March are shown in figure 3. The broken line in this chart is the regression line for March as shown in figure 1 and illustrates that the risk-factor method gives approximately the same line as the regression. The smaller variation in actual values of number of fires per day when combined data are used is also evident by comparison with the spread of points in the typical district curves.

The distance between the district lines (solid) and the combined districts line (broken) in figure 2 indicates the extent to which the expected number of fires for this particular district is greater or less than the average of the combined districts. The fact that some districts may expect more fires for a given rating than others indicates that the organized strength may be varied among districts. This information may help in deciding on the strength needed for the various districts.

In most cases the actual values follow the straight lines reasonably well. But in some instances individual values deviate greatly from the line. Many of these large deviations are probably due to the small number of days that had the same rating.

3/ Lindenmuth, A. W., and Keetch, J. J. A measure of the severity of fire seasons. Fire Control Notes 2(1). 1950.

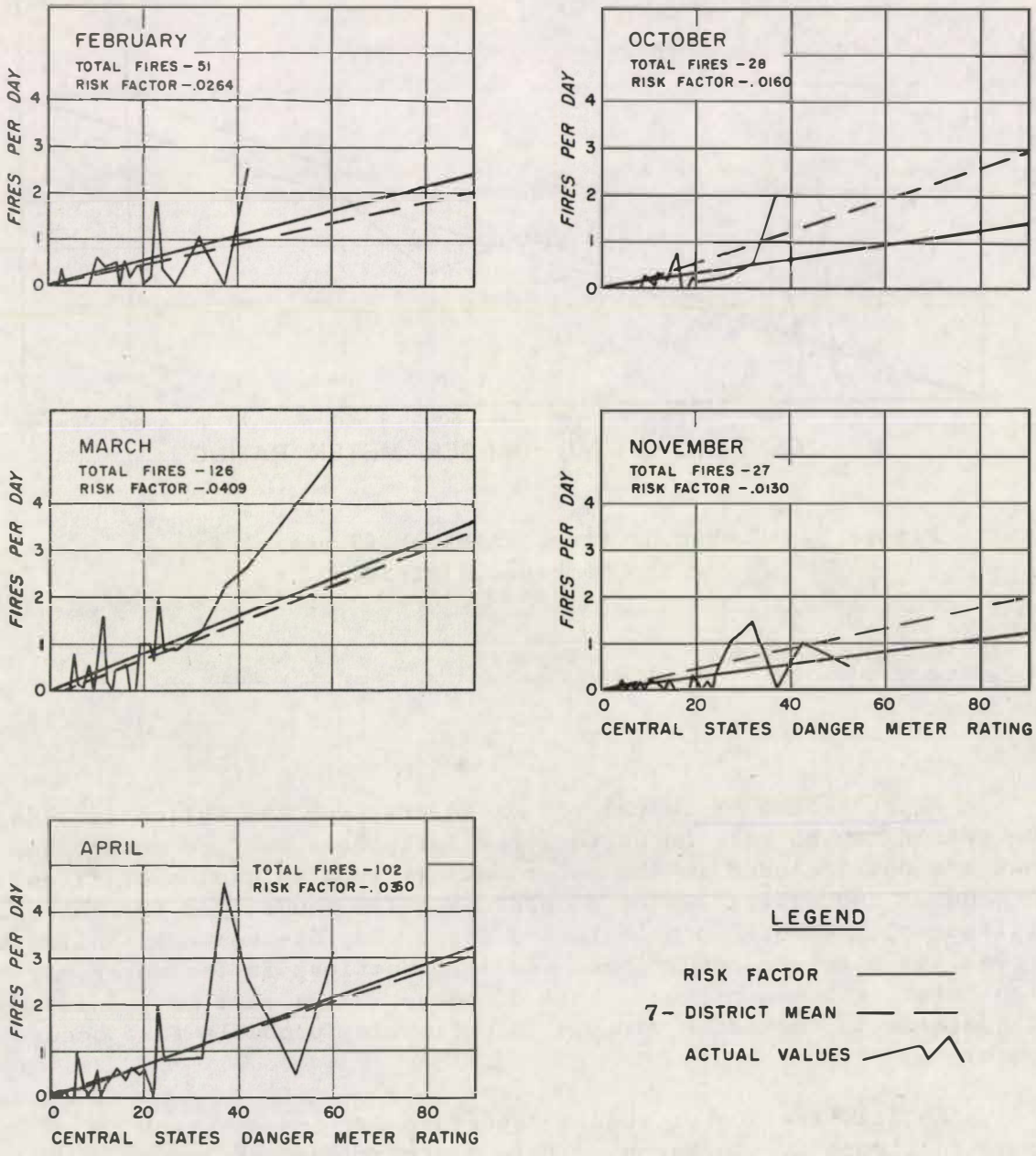


Figure 2.--Number of fires per day for one district by month.

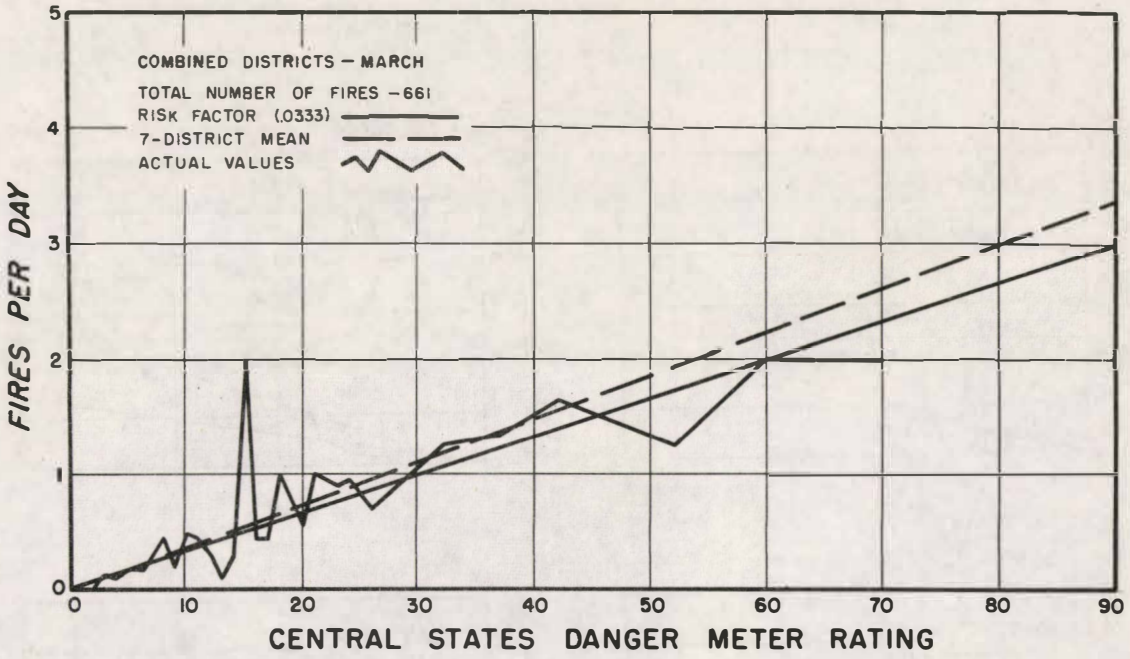


Figure 3.--Number of fires in March (7 years) for the combined districts.

Where groups of actual values depart from the estimated line, the reason may be attributed to local influences on fire occurrence that are not included in the meter ratings such as causes of fires, the number and activities of people using the woods, and the general attitude of the local people toward fire. Day-of-the-week, holidays, prevailing moisture conditions, and imperfections in the meter may also enter into the picture. All of these things must be considered in addition to the meter ratings in estimating probable fire occurrence.

An illustration of such a departure for one district is found in figure 2. In March on this district when the meter rating increased above 32, the number of fires per day was much greater than the estimated number to be expected. This departure may well be the result of local peculiarities of burning. A knowledge of the type of departure that occurs on a district may help in organizing the suppression forces. And if the cause of these departures can be determined, the fire-prevention needs for the district may be made clearer.

MULTIPLE FIRES COMPLICATE PREDICTIONS

When several fires occur during a number of days that have the same meter rating, the fires are seldom distributed evenly among the days. A district may have 3 or 4 or more fires on a certain day and none at all on other days. This makes the probability of a fire occurring on any one day somewhat less than the average probability of fire occurring on days having the same meter reading. For example, if there are 10 fires in 100 days, the probability of fire occurrence is 1 in 10 or 10 percent. However, since these fires could occur in 10, or 9 days, or even all in 1 day, the probability of any single day having at least one fire could range from 10 down to 1 percent.

Because the concentration of fires will influence fire-control plans, some estimate of it is desirable. Concentrations of fires (average for seven districts and all 5 months) by meter rating is shown by: (1) The percentage of days on which fires are reported (fig. 4), (2) the average number of fires per fire-day (fig. 5), and (3) by the frequency of occurrence of a given number of fires on individual fire-days (table 1). The two figures and one table show that the percent of days having fires and the average and maximum number of fires per fire-day all increase as meter ratings increase.

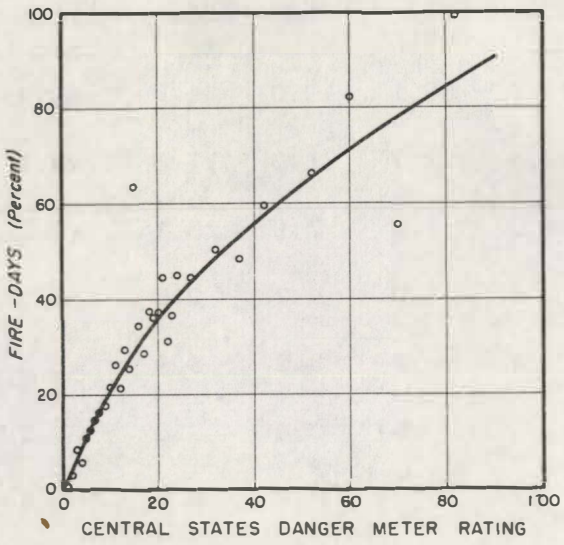


Figure 4.--Percent of days having one or more reportable fires by meter ratings.

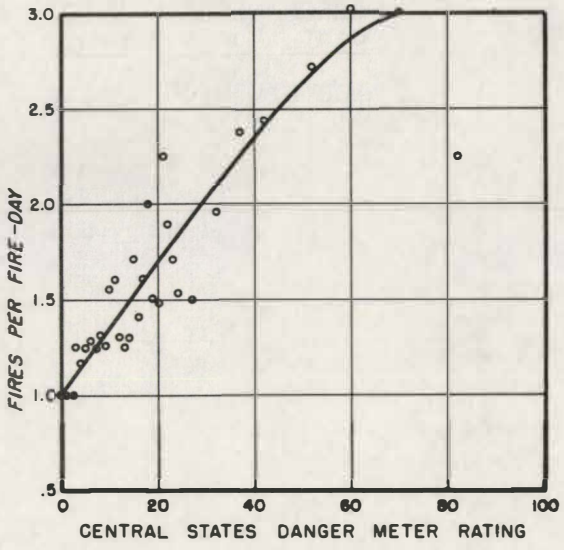


Figure 5.--Average number of fires per fire-day by meter ratings.

At ratings higher than 28, the average number of fires per day commonly exceeds 1.0, a probability of 100 percent. However, it is very unlikely that all of the days at any rating will have fires. This difference is accounted for by the fact that the average number of fires per fire-day starts with 1.0 and increases as ratings increase. For example, with a rating of 35, which is the average rating for all months when the average number of fires per day is 1.0, about half of the days have no reportable fires and the other half have an average of about two and a maximum of nine fires per day (table 1). The organization cannot be idle half of the days, however, because there are usually a large number of nonreportable fires that must be checked on the ground.

Table 1.--Percent of days on which various numbers of fires occurred, by meter rating groups

Number of fires on 1 day	Central States Danger Rating groups							All groups
	0-1	2-3	4-6	7-12	13-24	25-49	50-100	
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	100.0	81.0	83.3	73.9	66.1	49.0	34.6	63.1
2		14.2	10.6	18.5	22.7	31.2	17.3	23.1
3		4.8	6.1	4.2	7.2	7.9	23.1	7.2
4				2.8	3.0	4.7	9.6	3.5
5				.3	.2	3.2	3.9	1.2
6					.5	2.0	3.8	.9
7				.3		.7	5.8	.5
8					.3	1.0	1.9	.4
9						.3		.1
Total days having fires	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Although the information on probability of fire occurrence does not make it possible to predict the specific days on which fires will occur, there are some other indications that the probability of fire is greater on some days than others. For example, an analysis of the fires on one district showed that the risk factor on Saturdays and Sundays was about twice as great as for other days of the week.

Information on the extent to which fires are concentrated, supplemented by available local information as to when concentrations occur, should make for more practical use of predictions obtained from the Central States Danger Meter.

SIZE OF FIRE IS ALSO RELATED TO METER RATINGS

In spite of stronger control action at the higher meter ratings, the average size of fires increased as meter ratings increased (fig. 6). Although area burned cannot be assumed to indicate directly the rate of spread of a fire or how difficult it was to control, there is undoubtedly a correlation between size of fire and these two factors.

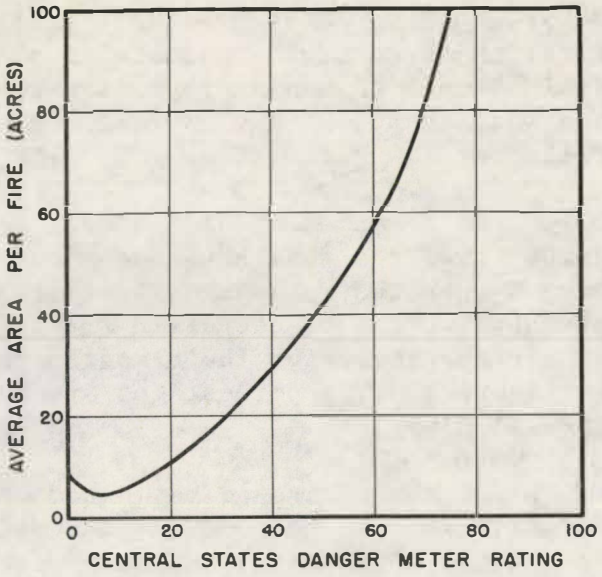


Figure 6.--Average area burned per fire.

Almost any fire, if left alone, will spread to large size. This is reflected in the slightly larger average area burned per fire at ratings of 1 to 3 than at 4 to 7. Ordinarily the organization is not on duty on days that have ratings of 3 or lower, so fires that do start may spread for some time before they are discovered and suppression work is begun.

Size of fire is influenced by many factors in addition to those included in the meter rating: Topography, number of sets (if incendiary), area of a debris-burning fire before it escapes, and type of fuel, to mention a few. Moreover, the speed of attack varies from place to place and time to time. Therefore, the size of fires varies greatly and so the average area burned per fire provides only a rough estimate of the size of fires that can be expected at various danger ratings and with the usual suppression force. It is significant, however, that size of fire, like the probability of fire, increases with increasing meter ratings. Since the probable size of fires has a strong influence on the strength of organization and the speed of action needed, estimates of probable size should help make fire-control activities more effective and efficient.

SEASONAL ESTIMATES HELP IN BUDGETING FUNDS

The immediate probability of fire occurrence as considered in the foregoing discussion is useful in the day-to-day planning of activities. But for other purposes, such as budgeting of funds and manpower, a more comprehensive view is needed. How many days during the season can be expected to have a rating of 50 or greater, 30 or greater, 20 or greater? What is the seasonal probability of fires on these days? And how great an area may be burned? What will it cost to man various fire-control positions during the season? And what chance of loss is assumed when these positions are not filled at low ratings?

An arrangement of the data to show the percent of days, number of fires that have occurred, and the area that has been burned when the maximum daily ratings have equaled or exceeded any given value can be useful in finding answers to these questions. Such percentages for the 5-month period considered here are shown in figure 7. The percentages are derived from the combined data for all districts.

If towers are to be manned at rating of 5 or greater, for example, it will be necessary to man them 60 percent of the days or a total of 90 days, and an average of about 4 percent of the fires will occur when towers are not manned.

The need for fire control multiplies in importance as rating increases. This is evidenced by the fact that less than 20 percent of the days have a maximum rating of 20 or more but on these days more than half the fires occur and cover more than three-fourths of the area burned.

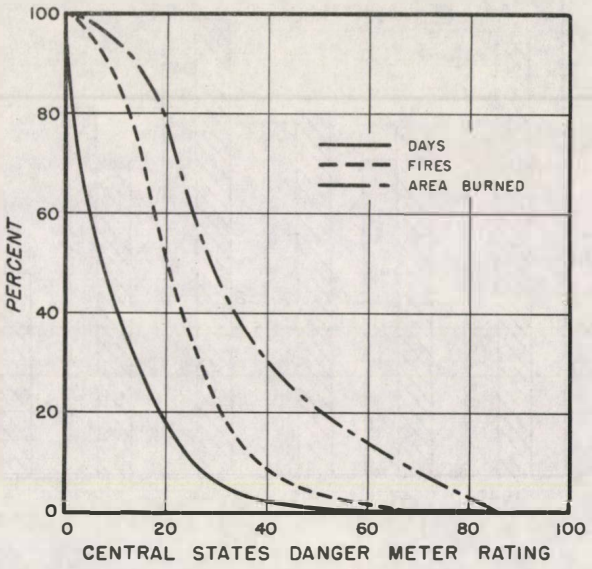


Figure 7.--Percent of total days, fires, and area burned that occurred at or above certain meter ratings.

Effective fire-prevention steps taken when the meter ratings are high may greatly reduce area burned. Likewise an organization in position to attack fires quickly and hard on these days can often prevent much area from being burned.

EFFECTIVENESS OF FIRE-PREVENTION PROGRAMS CAN BE ESTIMATED

Those responsible for fire-prevention work need some means to measure the effectiveness of their programs. Evaluation of these programs is often difficult because the number of fires may vary widely from year to year as a result of different weather conditions. Such variations in number of fires may obscure the result of prevention work. Number of fires alone is therefore not an adequate criterion of fire-prevention effectiveness. For example, in 1951 during the 5 months studied, there were 188 fires on the Clark National Forest; in 1952 there were 424 fires during the same period. But 1951 was a wet year and 1952 was dry, so more fires could have been expected in 1952 than in 1951. The problem in evaluating fire-prevention efforts therefore is to find out if the actual number of fires in 1951, 1952, or any other year is greater or less than could reasonably have been expected.

An estimate of the number of fires that could have been expected can be made by using mean-risk factors based on the records of several years. The expected number of fires is then obtained by multiplying the mean-risk factor by the sum of the daily maximum ratings for the specific period involved. This was done by months and the results summarized (fig. 8).

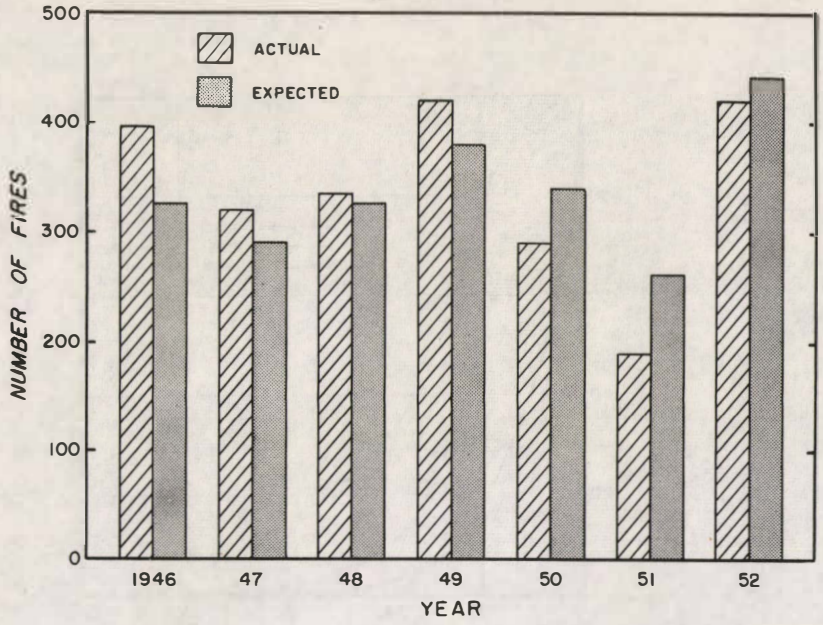


Figure 8.--Actual and expected number of fires by years.

During the period 1946-1952, the actual number of fires decreased in relation to the expected number. This decrease is clearly shown if the actual number of fires each year is expressed as a percentage of the expected number (fig. 9). Although the reduction was irregular over the 7-year period, it averaged 6 percent per year (dashed line). By extending the trend line it can be estimated that the number of fires for the next year should be only 74 percent of the number expected on the basis of the 1946-1952 mean risk factors. This percentage could be used as a standard, or objective, for that year.

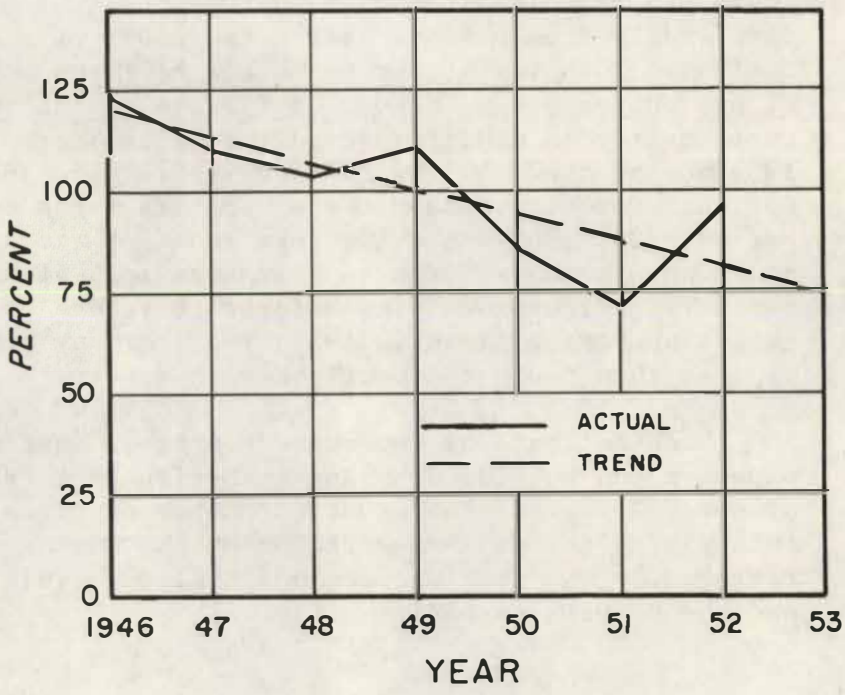


Figure 9.--Actual number of fires as a percent of expected number of fires by years.

The percentage relationship between actual and expected fires is independent of year-to-year variations in fire occurrence and so shows how much the factors not included in the meter rating influenced fire occurrence. Since changes in population and area protected have been minor, and activities on the national forest have remained fairly constant, it is reasonable to conclude that the relative decrease in fire occurrence is largely a result of effective fire prevention.

The above relationships are based on all causes of fires. Data for a single cause or for a particular prevention program can be analyzed similarly. Weaknesses in the prevention program can be revealed in this way and steps taken to remedy them.

SUMMARY

The main purpose of a fire danger meter is to measure and evaluate the conditions that contribute to fire danger. But if the past ratings given by any meter can be correlated with the actual occurrence of fires and a definite pattern established, the meter becomes a much more useful tool.

Such correlations were made on the Clark National Forest for a period of 7 years. It was found that the number of fires per day varies almost directly as maximum daily meter readings.

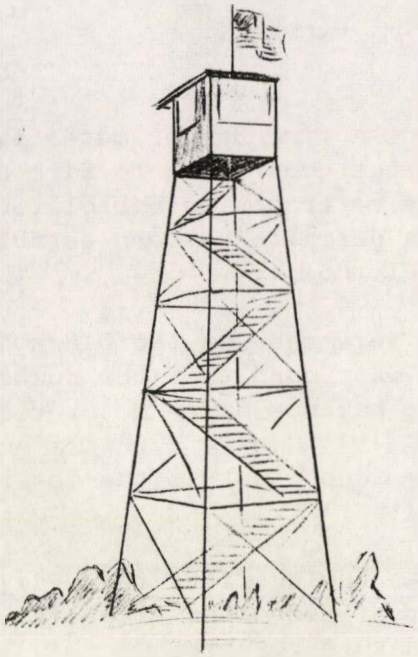
In addition it was found that as the meter rating increased the following increased also:

1. Percent of days having fires (fire-days).
2. Average number of fires per fire-day.
3. Average area burned per fire.

Since the relationships that exist in a local area (such as a ranger district on a national forest) are more useful than those for a forest as a whole, a method for estimating these relationships from a smaller sample of data has been developed.

At any given rating, fires tend to be concentrated rather than spread evenly over all the days having that rating. Information as to when these concentrations occur on any district may help to isolate and identify things that influence fire occurrence but are not taken into account by the meter.

A method of evaluating the results of fire-prevention efforts is given. Applying this method to the data for the Clark National Forest showed that over the 7-year period the actual number of fires decreased in relation to the expected number. This trend is credited to increasing effectiveness of the fire-prevention program.



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